MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

ETM4146 – DIGITAL WIRELESS COMMUNICATIONS

(TE)

23 OCTOBER 2018

9:00 A.M – 11:00 A.M.

(2 Hours)

INSTRUCTIONS TO STUDENT:

1. This exam paper consists of **5 pages** with **4 questions**.
2. Attempt **ALL questions**. All questions have equal weightage and the breakdown of marks within each question is given.
3. Please write all your answers in the answer booklet provided. Show all relevant steps to obtain maximum marks

Question 1

The block diagram of a typical digital wireless communication system is shown in Figure 1.1.

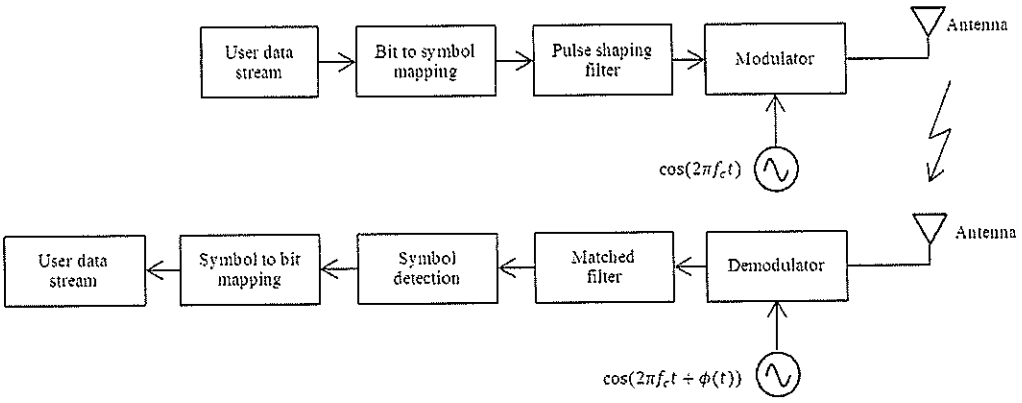

Figure 1.1

a) Describe the purposes of the following blocks:

i. Symbol detector [4 marks]

ii. Modulator [4 marks]

b) Suppose the channel has a bandwidth of W and the Nyquist zero ISI criterion must be satisfied. Discuss the design considerations for the pulse shaping filter for the following cases:

i. When symbol rate $\frac{1}{T} = 2W$ [5 marks]

ii. When symbol rate $\frac{1}{T} < 2W$ [5 marks]

c) The constellation diagram of the 4-QAM modulation is shown in Figure 1.2

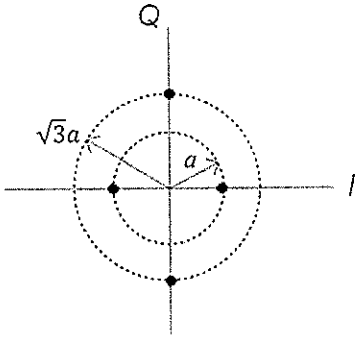

Figure 1.2

i. Determine the proper scaling a for normalizing the average transmitter energy to one. Assume all signal points are equally probable. [4 marks]

ii. Find the minimum distance between the pairs of signal points. [3 marks]

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Question 2

A ternary communication system uses three equiprobable signals of duration T seconds for transmitting data. The received signal at the m-th sampling instant is given by

$$y_m = \sqrt{E_s} s_m + n_m$$

where $s_m \in \{-1, 0, 1\}$ is the transmitted data symbol, and n_m is the zero-mean white Gaussian noise with variance σ^2. Suppose the maximum likelihood detector is used in the receiver.

a) Draw the decision regions (Voronoi regions) of the constellation. [4 marks]

b) Determine the conditional symbol error probabilities below:

$$P(error|1\ was\ sent)$$

$$P(error|-1\ was\ sent)$$

$$P(error|0\ was\ sent)$$

Hint: Express the answer in terms of Q-function, $Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-u^2/2} du$

[10 marks]

c) Determine the average probability of symbol error. [4 marks]

d) Derive the union bound for the average probability of symbol error. [7 marks]

Question 3

a) Suppose the received signal experiences an unknown delay and hence timing synchronization is needed to recover the correct symbol timing. Assume the upsampling factor $M = 9$, sampling rate 100 MHz, and three data symbols ($P = 3$) are used for sample timing recovery. The synchronization technique based on direct maximization of the output energy, computes the following function

$$J[k] = \frac{1}{P} \sum_{p=0}^{P-1} |r[pM + k]|^2$$

and the result is shown in Figure 3.1.

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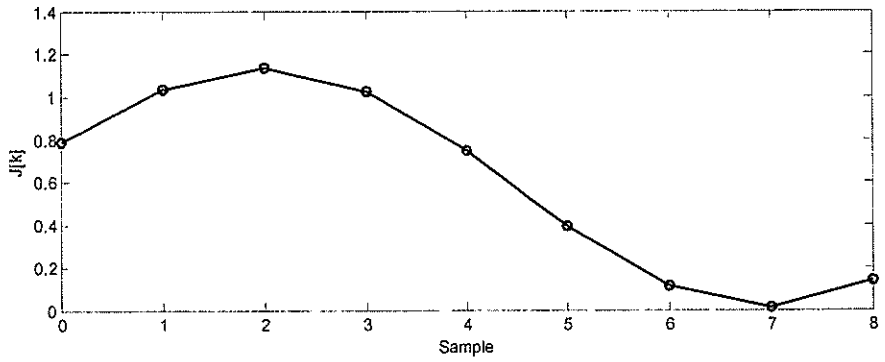

Figure 3.1

i. For optimum symbol synchronization, how many samples the received signal needs to be delayed before sampling? [4 marks]

ii. If the received signal is noisy, would increasing the number of symbols used for the synchronization method improves the accuracy? Explain your answer. [4 marks]

iii. If the actual delay experienced by the received signal is less than 10 ns, suggest a way to improve the timing synchronization accuracy. [4 marks]

b) Consider an OFDM system with 32 subcarriers. Suppose the wireless channel is frequency-selective and its frequency response is given in Figure 3.2 (upper plot). The OFDM receiver employs a zero-forcing frequency-domain equalizer and the transmitted and estimated data symbols are shown in Figure 3.2 (lower plot).

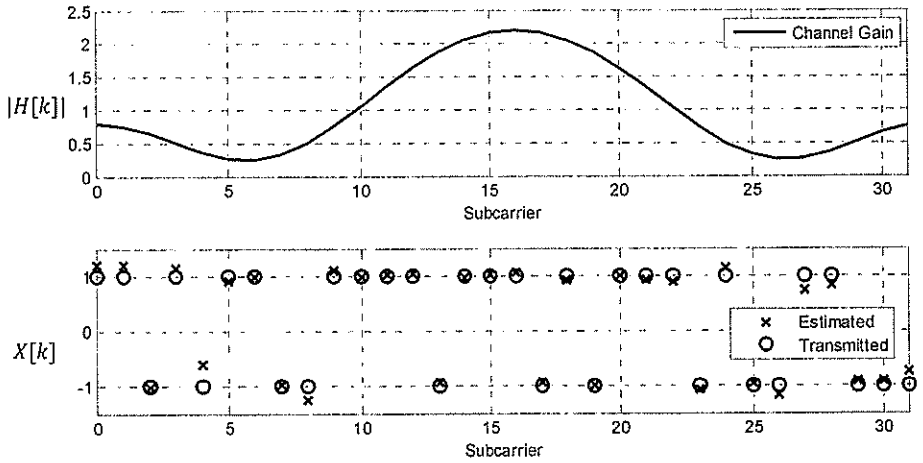

Figure 3.2

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It can be observed from the results that the equalization works well except when the channel gain is smaller than 1.

i. Explain why the estimate is less accurate when the channel gain is smaller than 1. [5 marks]

ii. Suggest another equalizer which will give better performance. [2 marks]

c) Suppose FFT length $N = 6$ and cyclic prefix of length 2 are considered for the OFDM receiver and the current received OFDM symbol (after removing CP and applying FFT) is given in the table below:

k	0	1	2	3	4	5
$Y[k]$	0.8	0.25+j0.25	1.25+j1.12	2.2	1.25-j1.12	0.25-j0.25

The transmitted symbols are given by $X[k]$ =[-1, 1, -1, 1, 1, -1]. Apply the least squares frequency-domain channel estimation to recover the frequency response of the channel.

[6 marks]

Question 4

a) Multiple-input Multiple-Output (MIMO) communications refers to a collection of signal processing techniques to enhance the performance of wireless communication systems using multiple antennas at the transmitter, receiver, or both. MIMO techniques can be divided into two categories: *spatial diversity* and *spatial multiplexing*. Explain these two concepts.

[8 marks]

b) Illustrate using proper diagrams, the four types of antenna configurations and the nomenclature used for describing each configuration.

[4 marks]

c) Suppose a MISO channel with N_T transmit antennas and the channel vector $\boldsymbol{h} = [h_1, h_2, \ldots, h_{N_T}]$ is fixed and known to the receiver only. Let $|h_i|^2 = a, \forall i$.

i. Show that the capacity of this channel is the same as the capacity of a SISO channel. [5 marks]

ii. Why are the capacities of MISO and SISO systems the same under the assumption that channel state information (CSI) is only known to the receiver? [4 marks]

iii. Can the result be interpreted as saying that there is no benefit whatever to having multiple transmit antennas with CSI only known to the receiver? Explain your answer. [4 marks]

End of paper.